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MID-YEAR REPORT

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TITLE: EXPERIMENTAL TEST OF PLANT CANOPY REFLECTANCE MODELS ON COTTON

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Principal Investigator

This grant was requested to begin in July, but due to the short lead time, funding actually was accomplished as of September 1, 1973. The funding date was being pushed to allow field data to be collected on the current cotton crop. The Director of the United States Department of Agriculture, Agricultural Research Service (USDA, ARS) at Weslaco, Texas, agreed to pay salaries of three student assistants and the principal investigator for the period July 15 to August 31, 1973. This support was a result of interest in this project generated by contact with personnel at USDA, ARS involved in the same general area of research.

This report will outline data collected at the USDA, ARS Experimental Farm and model calculations in progress at Pan American University.

FIELD DATA:

Spectroradiometric data on the bi-directional reflectance function $\rho(\theta,\phi;\theta',\phi')$ was collected for a cotton canopy as a function of observer zenith angle θ, observer azimuth angle ϕ, and solar zenith angle θ'. The actual angles for which data were obtained are shown in Table 1. This table indicates the dates for which data were obtained when the cloud formation was less than an estimated 10% of the hemisphere.

This area is about 40 miles from the Gulf of Mexico and the prevailing winds blow inland such that cloud formation increases during the course of each day. For each angle θ, six azimuthal angles ϕ were chosen: east, northeast, north, northwest, west, and southwest; a complete spectral scan was made for each angle θ and ϕ as well. For each series of azimuthal angles at a given observer angle, the reflectance $\perp$ to a standard panel was measured.

The standard reflectance panel was constructed of plywood that had been spray-painted with a flat white latex paint. The purpose of the reflectance panel

TABLE 1

			ANGLE θ				
SOLAR ALTITUDE	TIME (CDT)	REFERENCE PANEL	0°	15°	30°	45°	60°
75 arctangent 2.35	8:40						
60	9:40						
45	10:40	8/10	8/10		8/10		
30	11:40	7/31 8/1	7/31 8/1	8/10	7/31		
15	12:40	7/31 8/1	7/31 8/1		8/1	7/31	
0	1:40	7/31 8/1	7/31 8/1		8/1	8/1	
15	2:40	7/31 8/1	7/31 8/1	7/31	8/1		
30	3:40	7/31					
45	4:40						
60	5:40						

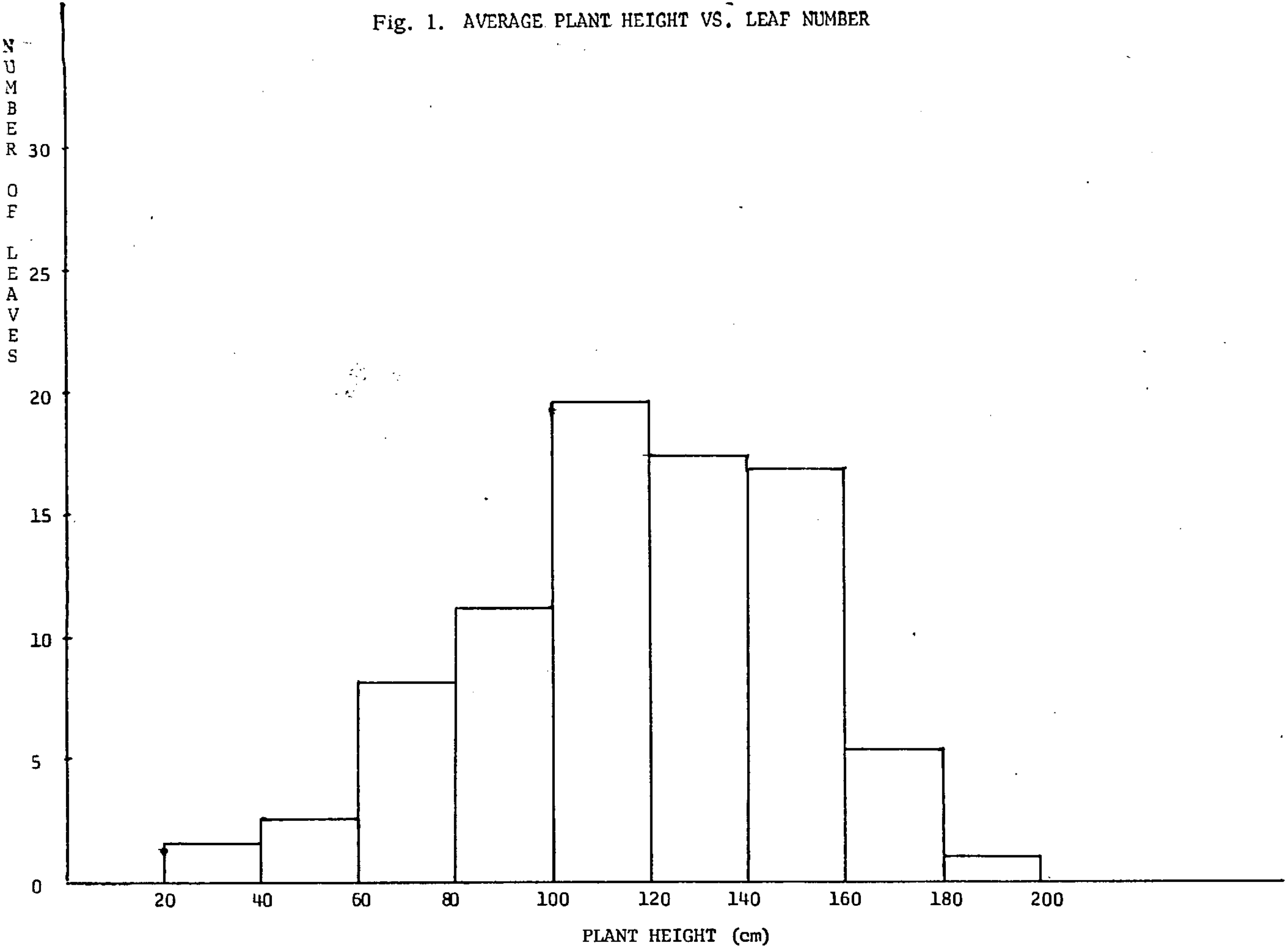
measurements was to find the absolute intensity of light coming from the sun at that particular time. Our procedure was to paint small plywood squares at the same time the field panel was painted and to use the USDA, ARS Beckman DK-2A laboratory spectroradiometer to measure the absolute reflectance of the small squares by a procedure discussed elsewhere (1).

The field spectroradiometer used in the experiment was an instrument obtained on loan from the USDA, ARS. The ISCO Model SR has a 1.83 meter fiber optics probe for which a mount was built that could be adjusted for any zenith angle and easily moved through a variety of azimuthal angles. Field data were obtained from a 6-meter-high portable paint scaffold assembled in the cotton field. The field of view was determined to be a circle of 1.2 m diameter, sufficiently large to give a reasonable average over several plants. It should be noted that there were no row effects visible in our field.

Plant parameters that were measured fall in two categories, physical and optical. The physical parameters were 1) the number of leaves per unit volume as a function of plant height, 2) the total area of the leaves as a function of plant height, 3) leaf area projections on a horizontal plane and on vertical orthogonal planes, and 4) leaf angle distribution as a function of height. The optical parameters were the single-leaf reflectance and transmittance as a function of plant height.

A time-lapse mechanism was constructed to operate a 16 mm movie camera such that single frames could be exposed at intervals of one per second up to one per hour. Time lapse movies were taken to answer the questions on a qualitative basis, "How much does leaf angle and leaf orientation change during the course of a day?" The films obtained clearly demonstrate that the plants show heliotropic effects, wilting during the hottest part of the day, and mechanical movement from the wind. It was found that the latter effect nearly obliterated

Fig. 1. AVERAGE PLANT HEIGHT VS. LEAF NUMBER



the previous ones. More work is planned to obtain films demonstrating all the above mentioned effects.

CALCULATIONS:

Field spectroradiance data were recorded on a strip chart recorder. These data have been digitized along with reflectance panel measurements made at the time. Work is in progress to reduce data to absolute reflectance. Fig. 2 shows typical radiance data that have been digitized in 50nm intervals from 400nm to 1150nm. These intervals were chosen because the USDA, ARS Beckman DK2-A spectroradiometer used to measure the reflectance of our standard panel is incremented in 50nm intervals. The intensity scale is dependent upon instrument calibration and the units are relative.

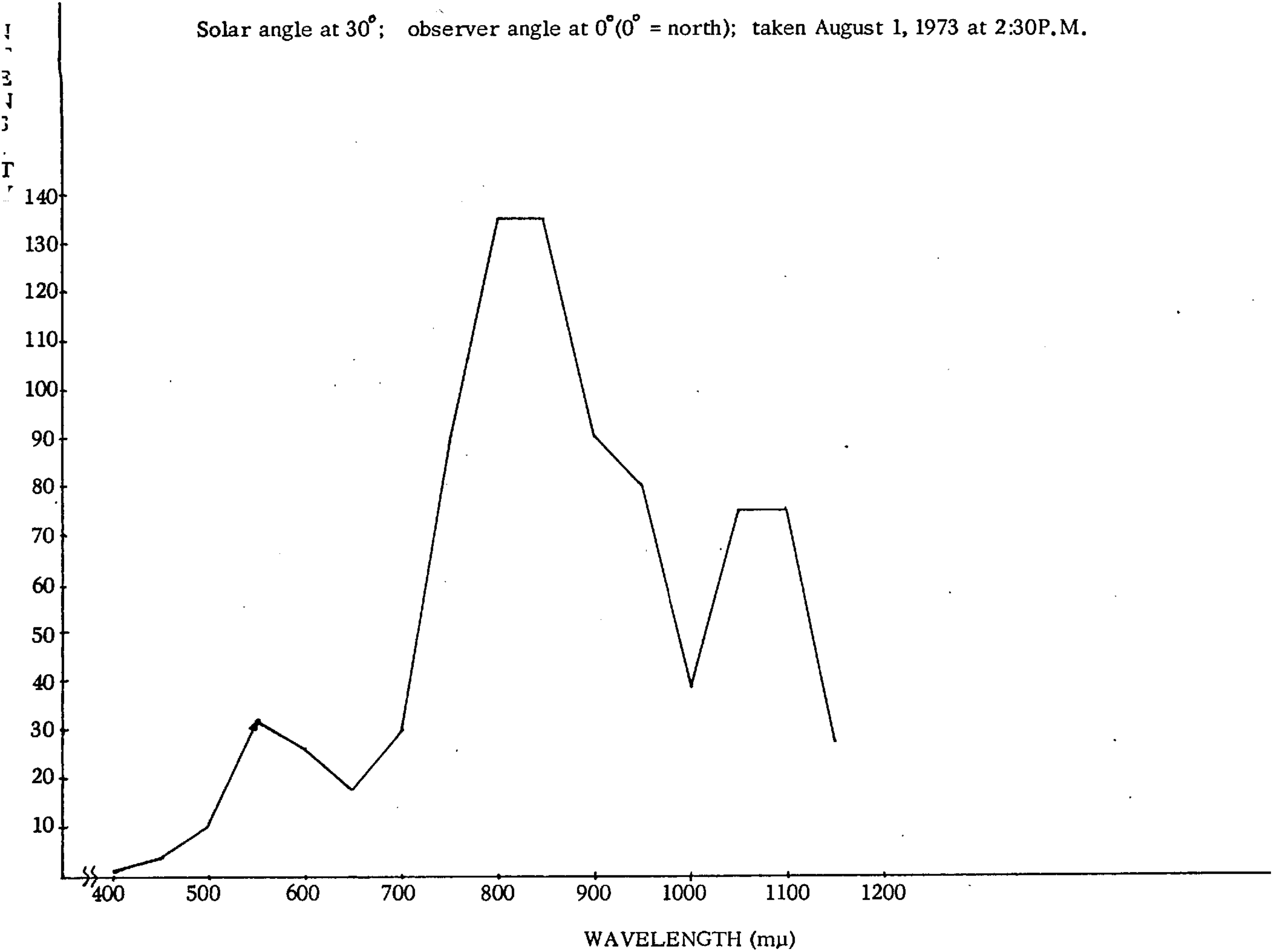
A female student is working on the job of programming the mathematical model of Suits (2) on our computer. The program is nearly operational and should produce reflectance curves within several weeks. The models of Smith and Oliver (3) and Beeth (4) have been studied for purposes of data collection; however, neither has been programmed. Smith plans to send a copy of his program within a short time; Beeth has agreed to send a copy of his program when it is written.

PLANS AND PROJECTIONS:

The project was a rather ambitious undertaking in terms of getting all three models evaluated. We fully expect to be able to implement at least two models, namely, Suits and Smith, with our present data. A new cotton crop will be available for study this June and July, as well as crops of sorghum and corn. It would be desirable to test the models on their ability to discriminate among crops normally grown in the same geographical region during the same season. In addition, winter wheat is a rather economically important crop at this time and should be investigated in terms of determining the most appropriate model for predicting bi-directional reflectance of a grass-like plant as opposed to a broad-leaf plant as is being studied in this effort.

Fig. 2. RADIATION INTENSITY VS. WAVELENGTH

Solar angle at 30°; observer angle at 0°(0° = north); taken August 1, 1973 at 2:30P.M.



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(3) J. A. Smith and R. E. Oliver, Dept. of Watershed Sciences, Colorado State University, Fort Collins, Colorado, Proceedings of the Eighth Symposium on Remote Sensing of Environment; (1973) University of Michigan, Center for Remote Sensing Information and Analysis, Ann Arbor, Michigan.

(4) D. R. Beeth, NRC Postdoctoral Fellow, NASA, JSC, Houston, Texas, (to be published).